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# Application of Rare Earth Permanent Magnet on Magnetic Abrasive Machining

Y. Chen[1] and D.Y. Ju[2]

[1] Department of Mechanical Engineering, Anshan University of Science and Technology, China

[2]Department of Mechanical Engineering, Saitama Institute of Technology, Japan

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**Abstract.** Because of the raw material elements and its purity and so on, the Nd-Fe-B permanent magnet, the strongest magnetic material, which needs artificial synthesis, can hardly be used directly. The performance of the permanent magnet has not yet been greatly developed owing to the limitation of the artificial synthesizing technology, of the powder sintering technology and that of the application. In this paper, the magnetic abrasive machining method as a new application is put forward, and from this viewpoint, are discussed the performance and the processing technology of the permanent magnet and the magnetic abrasive machining method. A sintering route combining the direction heat treatment technique to increase the magnetic energy is suggested.

## Introduction

In the permanent magnet materials domain, the development of the Nd-Fe-B permanent magnet has now undergone nearly 20 years. Through the raw material depuration, powder smelting, heat treatment, surface treatment and so on, each kind of technological progress in the Nd-Fe-B permanent magnet leads to the continuous enhancement of its permanent magnetic performance, which also needs to develop the new magnetic materials, and that a new application is to be sought for has become the common request. The magnetic abrasive machining is regarded as one kind of new permanent magnet application.

The magnetic abrasive machining is a method in which the magnetic field (lines of magnetic force) is used to precisely machine the surface of the workpiece [1]. When the magnetic abrasive particles are filled between N-S magnetic poles, owing to the application of magnetism, the magnetic abrasive particles become a hard magnetic brush along the lines of magnetic force (The magnetization is generated). When the workpiece is inserted into this magnetic field, and when the relative movement between the workpiece and magnetic poles is given, the magnetic abrasive particles will press and polish the surface of the workpiece (Figure 1).

## Performance demand of permanent magnet

There are a lot of factors that influence the processing efficiency and the quality of the magnetic abrasive machining. In the magnetic abrasive machining, the magnetic abrasive particles present a free state; rely on the function of the magnetic field to enclose on the surface of workpiece. When the rotation speed of workpiece is too fast, because of centrifugal function, the magnetic abrasive particles breaks away from the restraint of the magnetic force and flys to the outside. So, the rotation should be controlled within some certain speed. Therefore, the magnetic force of

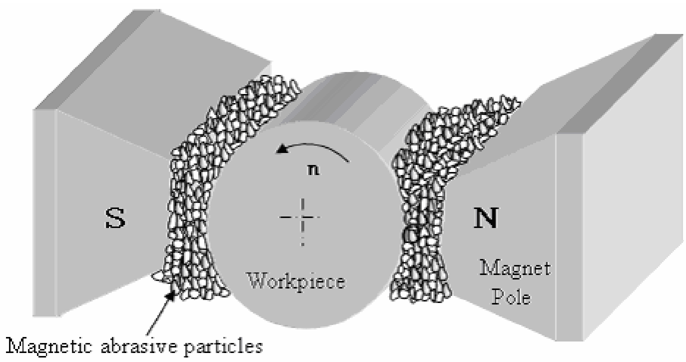


Fig. 1 Principle of magnetic abrasive machining

permanent magnet is one of the main influencing factors of polishing efficiency.

Now the experiment shows [2]:

$$F = K D^3 H ( \partial_H / \partial x ) \quad (1)$$

where F is Magnetic force, K is Susceptibility, D is Iron particles diameter, H and ($\partial_H$ / $\partial$x) are magnetic density and change rate, respectively.

The polishing effect considered, the diameter of the magnetic abrasive particles and suscepti-bility of the material are almost of fixed value, so, the intensity of magnetic induction of permanent magnet can only be increased for improving the polishing efficiency.

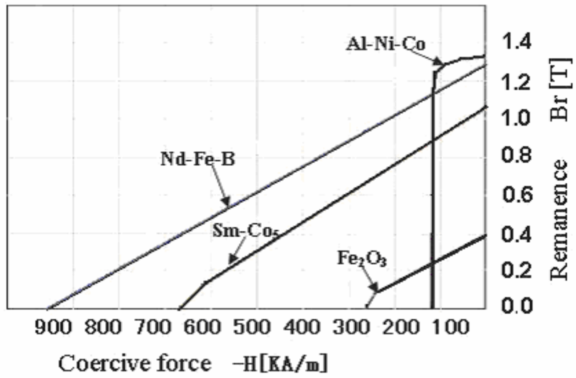


Fig. 2 Deperm curve of main permanent magnet

The intensity of magnetic induction of permanent magnet is determined by the product (also called the biggest energy product, which expresses the permanent magnet energy)of the intensity of magnetic induction and the demagnetization of permanent magnet in the air gap, besides, the intensity is related to the volume of the magnet and air gap.

Permanent magnet is various in types.The material ingredients of the rare earth and technology of the artificial synthesis is different. But , its performance index is not different. In order to comply with the market demand and the enhancement of processing efficiency, the permanent magnet used in magnetic abrasive machining requires, under the volume small premise, a higher energy product and higher magnetic-flux density. Seen from Fig. 2, the Nd-Fe-B (neodymium-iron-boron) magnet, a typical example of the rare earth magnet, and the strongest man-made permanent magnet so far, demonstrates a higher coercive force and the residual magnetic-flux density, and the Nd-Fe-B magnet's magnetic energy product is also higher, and along with the HDDR (hydrogenation disproportionation, desorption and recombination) technology and the progress in nanometer synthesis magnet technology, the magnetism performance also obtains the rapid enhancement, and it is possible for the permanent magnet to obtain bigger magnetic field strength in the very small space [3].

Moreover, when the magnetic abrasive machining processing is used, the magnetic abrasive machining working temperatures generally reach 200 centigrade because of the cooling function of the polishing liquid. However, Curie temperature of the Nd-Fe-B permanent magnet may reach 312 centigrade, which conforms to the magnetic abrasive machining requirement in the real working condition.

## Nd-Fe-B permanent magnet

Nd-Fe-B material is a type of intermetallic compound, which has a composition of two rare earth atoms: 14 iron atoms and one boron atom. Besides the main phase $Nd_2Fe_{14}B$ in Nd-Fe-B permanent magnet material, a small number of Nd-rich phase ($Nd_2FeB_3$), boron-rich phase ($Nd_2Fe_7B_8$) as well as other phases exist. The Nd-rich phase provides the pinning of the domain walls so that Nd-Fe-B magnet has high coercive force. The main phase $Nd_2Fe_{14}B$ is a square crystal structure, which is extremely important for obtaining the high magnetic properties (see Fig 3). Among them, the main phase and the rich Nd phase are two most important phases of determining Nd-Fe-B permanent magnet magnetism performance [4]. The main phase $Nd_2Fe_{14}B$ only has the single axle aeolotropism hard magnetism phase in the Nd-Fe-B permanent magnet and the main phase has higher saturation magnetization intensity, magnetism crystal, and the dissimilitude field of each phase.

The Nd-Fe-B permanent magnet manufacture technology is divided into two kinds: sintered and bonded. Generally speaking, Nd-Fe-B sintered magnet is the compact aeolotropic magnet, which is made with the powder metallurgy method, but the Nd-Fe-B bonded magnet is obtained by means of instant cooling of the microcrystal powder, and caking the powder into magnet lumps again with the

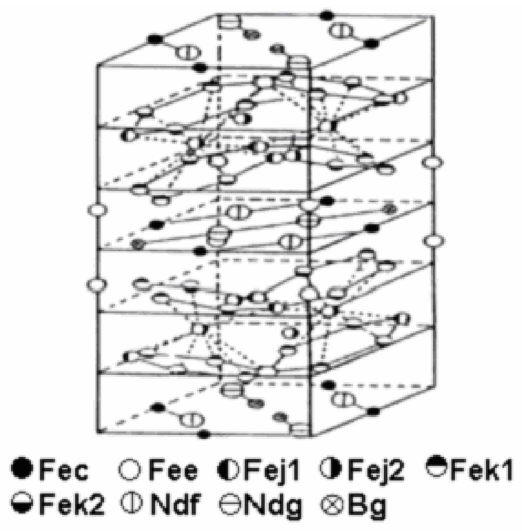


Fig. 3 Square crystal structure of $Nd_2Fe_{14}B$

polymer or other adhesive. Thus, Nd-Fe-B bonded magnet is the non-compact isotropism magnet. Consequently, the permanent magnetism performance of Nd-Fe-B sintered magnet is higher than that of the Nd-Fe-B bonded magnet.

In the production of Nd-Fe-B permanent magnet, the rich Nd phase is separated out and agglutinated, and the main phase surface magnetic domain occurrence spot is eliminated. The rich Nd of the Nd-Fe-B permanent is non-ferromagnetism magnet, therefore, there is a problem in reducing the magnetization, and the rich Nd can easily cause the Nd-Fe-B permanent oxidized, so it is necessary to reduce the rich Nd as much as possible. Here two methods are recommended.

First, in the alloy that is nealy composed of the $Nd_2Fe_{14}B$ composition, the primary crystal iron is separated out by means of the Strip Casting control. Simultaneously, the $Nd_2Fe_{14}B$ will be heated up to 1027K or above in $H_2$ so that the base body will be decomposed into very small $NdH_2$, $\alpha$-Fe and $Fe_2B$ organizations, then dehydrogenation processing will be completed within the same temperature range. During the dehydrogenation, Nd also produces very small $Nd_2Fe_{14}B$ chemical compounds that combine with each other, thus the higher coercive force of permanent magnet powder will be obtained. But, in the hydrogenation process, the part of hydrogen atom will enter into the magnet's crystal lattice. In such a case, the dehydrogenation processing will be very difficult.

Second, the aeolotropism powders can be obtained by increasing Ga and Co elements in the Nd-Fe-B alloy. By compressing these powders, the raw material powder uniformity of the granularity can be enhanced; the sintered body organization may become very tiny, and makes the coercive force bigger so much so that the bigger magnetic energy product will be obtained.

## Conclusions

The magnetic abrasive machining requires that the permanent magnet performance should be the high magnetic energy product. Therefore, the sintered Nd-Fe-B permanent magnet is widely chosen, and this method has already received good processing effect in the actual application. If the raw material is chosen, the rich $Nd_2Fe_{14}B$ which enhances the magnetic energy product should be chosen. The magnetic abrasive machining is one kind of new application domain for permanent magnet, but the magnetic abrasive machining technology, compared with the traditional technology, still has shortcomings, for example, the processing efficiency is not higher. One of the reasons is that the magnetic energy product and the surplus magnetic-flux density of permanent magnet are not ideal. The new manufacturing technology will continue to be found in the near future, so that the higher magnetism performance of the permanent magnet can be developed.

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